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Berthella (Opisthobranchia: Pleurobranchidae) from the Northeast Pacific Ocean Prey on Plakinid Sponges (Homoscleromorpha: Plakinidae)

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Abstract. Field observations, laboratory feeding trials, and examination of the gut contents of freshly collected specimens indicate that *Berthella californica* and *B. strongi* from the NE. Pacific Ocean prey on plakinid sponges, including *Oscarella carmela*, a recently described species which lacks skeletal elements. These results strengthen the case that species of *Berthella* are specific to plakinids, especially by documenting the association in a new geographic region. The existence of specific predators of *O. carmela* also supports the hypothesis that this sponge is native to the NE. Pacific Ocean but was previously overlooked or misidentified in the wild.

INTRODUCTION

Pleurobranch opisthobranchs in the genus *Berthella* are widespread, often conspicuous members of the benthic epifauna (Thompson, 1976; Willan, 1984). The prey of only four species has been determined with certainty (Delaloi & Tardy, 1977; Willan, 1984; Cattaneo-Vietti, 1986; Picton, 2002; Goddard, 2005). These records, which come from the Mediterranean Sea, NE. Atlantic, and SW. Pacific Ocean, suggest that species of *Berthella* prey specifically on plakinid homoscleromorph sponges, which according to recent studies are genetically more similar to the Eumetazoa than to the rest of the Porifera (Nichols et al., 2006; Sperling & Peterson, in press). A few species of *Berthella* have also been surmised to feed on ascidians, based on (1) the known diets of species of the related *Pleurobranchus* (Thompson, 1976; Thompson & Colman, 1984), and (2) reports of association with ascidians in the field (MacFarland, 1966; Behrens & Hermosillo, 2005). However, actual consumption of ascidians by species of *Berthella* has not been observed, and the simple occurrence of grazing opisthobranchs on sessile organisms is insufficient to infer direct predation, especially in space-limited, encrusting communities where overgrowth of one species by another is common (e.g., Rützler, 1970; Jackson, 1977; Russ, 1982).

Nothing has been published previously on the diets of *Berthella* from the northeast Pacific Ocean. Here I present field and laboratory observations on the diets of *Berthella californica* (Dall, 1900) and *B. strongi* (MacFarland, 1966). *Berthella californica* is a conspicuously colored species that reaches 50 mm in extended length and ranges from the Sea of Japan, across the north Pacific, and into the eastern Pacific as far south as the Galapagos archipelago (Martynov, 1998; Behrens & Hermosillo, 2005; Camacho-Garcia et al., 2005). *Berthella strongi* is drab in color compared to *B. californica*, reaches 25 mm in extended length, and ranges from Vancouver Island, British Columbia to Punta Rosarito on the Pacific coast of Baja California (Behrens & Hermosillo, 2005).

METHODS AND RESULTS

1. *Berthella californica*

Field observations and observations of gut contents: While studying the intertidal opisthobranchs of Cape Arago, Oregon (43°20′N, 124°22′W), I found numerous specimens of *Berthella californica* (Goddard, 1984; unpublished observations), but recorded only two individuals associated with potential prey items. One of these was found in July 1998 on the thinly encrusting compound ascidian *Diplosoma listerianum*; the other in August 1986 under a cobble next to a thin, tan-colored slimy sponge. This sponge has recently been described from Monterey Bay, California by Muricy & Pearse (2004) as *Oscarella carmela*. However, no evidence of feeding on either of these organisms was observed on these dates.

I also examined microscopically the fecal strands of three specimens freshly collected from Cape Arago in April 1991 (using 6% NaOCl to clean any skeletal elements and acetic acid to differentiate calcareous from siliceous spicules). From one individual these contained a mixture of poecilosclerid sponge spicules, including an unidentified hymedesmiid, and a few spicules characteristic of the thinly encrusting *Zygherpe hyaloderma*. From another, they contained some siliceous diod spicules characteristic of a plakinid homoscleromorph sponge (Austin & Ott, 1987; Muricy et al., 1998) and from the third, numerous siliceous triods characteristic of a plakinid (Austin & Ott, 1987; Muricy et al., 1998), as well as a few spicules from unidentified poecilosclerid sponges. Additionally, I

dissected the alimentary tract of one specimen freshly collected in February 1987 from an unidentified sponge at Cape Arago by T.A. and K.R. Wayne and found no recognizable contents other than a few sand grains.

Laboratory feeding trials: To test whether or not *Berthella californica* prey on *Oscarella carmela*, I collected from the protected rocky shore at Cape Arago one specimen of the sponge on 25 June 2006 and two specimens of the slug on 27 June 2006 and conducted a simple feeding experiment at the Oregon Institute of Marine Biology. At 12 noon on 27 June, I placed one 22 mm long specimen of *B. californica* with a 1 cm^2 piece of *O. carmela* in a shaded 8 × 8 × 14 cm high, plastic container (with mesh covered openings to allow water exchange) on an indoor, black, flow-through water table at ambient ocean temperature (approximately 12°C). Within 1 hr the slug had found and consumed most of the sponge, and after another 1.5 hr had consumed the remainder. This slug was preserved 1.25 hr after finishing the sponge and later deposited in the California Academy of Sciences (CASIZ 173046). Starting at 4:30 pm the same day, I repeated this with the second slug, also 22 mm long. This specimen did not feed on (or even appear to locate) *O. carmela* over the next 22 hr. I then placed the two in direct physical contact, and the slug immediately positioned its oral veil over the sponge and began to feed. After 5 min I removed the sponge and replaced it with a similarly sized piece of *Halisarca sacra*, a thin, tan-colored dendroceratid slime sponge superficially similar to *O. carmela* in its color, thinness and lack of skeletal elements. After 15 min the slug had not attempted to feed on this sponge. I then replaced the *Halisarca* with the *O. carmela*, and the slug immediately began feeding again. Two and a half hr later, the slug had consumed the entire piece of *O. carmela*. I then placed a piece of *Halisarca* with the slug. After two days with no sign of feeding, I placed the anterior end of the slug in contact with the *Halisarca*. The slug slowly but steadily turned away from the sponge and crawled away. I left the *Halisarca* and the slug in the same container for an additional 6 days, during which there was no evidence of feeding on the sponge.

For comparison to the above trials, I placed in an identical container for the same 10-day time period three specimens of the dorid nudibranch *Hallaxa chani* with one piece each of *Halisarca sacra* and *Oscarella carmela*. *Hallaxa chani* specializes on *Halisarca sacra* (Goddard, 1981, 1984, 1998; as *Halisarca* sp.). These slugs quickly consumed all of the *Halisarca*, but did not eat any *O. carmela* during the 10-day period. I then preserved the *Hallaxa chani*, the *O. carmela*, and an additional piece of *Halisarca sacra* from Cape Arago and deposited them in the California Academy of Sciences (CASIZ 173047, 173045, 173043, respectively).

2. *Berthella strongi*

On 7 October 2006 I found one specimen of *Berthella strongi*, 5 mm long, on *Oscarella carmela* on the underside of a low intertidal cobble in a boulder field located 2 km west of the Ellwood Pier (34°25.80′N, 119°55.36′W), Goleta, Santa Barbara County, California. I collected the sponge with the slug and held them together in a shaded dish of seawater at 18°C for one day. During this time the slug moved only slightly from its original position and, as observed under a dissecting microscope, had grazed overnight a small portion of the sponge. The slug and the sponge were then preserved and deposited together in the Santa Barbara Museum of Natural History (SBMNH 369472).

On 4 November 2006 I found three additional specimens of *Berthella strongi*, 6, 10 and 10 mm long, all in contact with *Oscarella carmela* underneath three different rocks in the low intertidal at the Ellwood boulder field. I collected all three specimens and held them separately with 67, 67 and 75 mm^2 of *O. carmela*, respectively, in glass finger bowls of seawater at 16–19°C for 2.5 days. Approximately 75 mm^2 of *O. carmela* was held separately in another finger bowl as a control. The sponges were found adjacent to the slugs, attached to fragments of rigid, sand-encrusted, polychaete worm tubes. The finger bowls were covered by a damp cloth, shaded, and their water changed daily. The position of the slugs (on or off *O. carmela*) was checked 4 times daily. The 6 mm slug and one 10 mm slug spent the entire 2.5 days on *O. carmela*, consuming 17 and 60 mm^2 of the sponge, respectively. The other 10 mm specimen spent all but a few hours of day two on the sponge and also consumed 60 mm^2. The control sponge showed no change in area during the experiment. At the conclusion of the feeding experiment, the 6 mm slug and the remainder of its sponge prey were preserved in 70% ethanol and deposited together in the Santa Barbara Museum of Natural History (SBMNH 369473), as was the *O. carmela* used as a control (SBMNH 369474).

DISCUSSION AND CONCLUSIONS

All four *Berthella strongi* found in this study were associated with *Oscarella carmela* in the wild and readily consumed this sponge in the laboratory. *Berthella californica* also consumed *Oscarella carmela* in the laboratory, and given one record of its occurrence next to this sponge at Cape Arago, likely also preys on *O. carmela* in the wild. Additionally, A. Draeger recently found a mating pair of *B. californica* next to *O. carmela* at 9 m depth in Monterey, California (J. S. Pearse, personal communication, 29 June 2006). *Oscarella carmela* lacks skeletal elements and would therefore be missed in examination of gut contents, possibly explaining the lack of recognizable

gut contents in the specimen of *B. californica* collected from an unidentified sponge at Cape Arago in February 1987.

Evidence in the field of feeding by *Berthella californica* was sparse compared to that for other Nudipleura (Wägele & Willan, 2000) at Cape Arago (personal observations). However, *O. carmela* is thin, drab in color, and easily overlooked without an established search image, especially when grazed (Muricy & Pearse, 2004; personal observations). Moreover, observations were made primarily during the day, and many species of *Berthella* and other pleurobranchs are nocturnal, taking refuge under rocks during the day (Delaloi & Tardy, 1977; Willan, 1984; R. Willan, personal communication). Additionally, *O. carmela* appears to be rare at Cape Arago (personal observations), and except for the skeletal evidence of plakinids in the fecal strands of *B. californica*, other species of plakinid sponges have not been observed at this locality. *Berthella californica* may be effectively limiting the abundance of plakinids intertidally at Cape Arago, and the most *B. californica* observed there at any one time were (on two occasions) crawling out in the open, in boulder field sea urchin barrens before sunrise (personal observations).

The feeding trials conducted in this study commenced the same day the slugs were collected. Consequently, the difference in the initial responses of the two specimens of *B. californica* to the presence of *O. carmela* may simply have reflected the time period since each had last fed in the field. However, dissimilar diets in the wild and ingestive conditioning (Hall et al., 1982) might also explain this difference. The gut contents observed in this study indicate that at least some individuals of *B. californica* ingest other plakinid sponges, species of which have been recorded previously from the northeast Pacific Ocean (Austin & Ott, 1987; Lehnert et al., 2005).

Given the nocturnal habits of many pleurobranchs (Willan, 1984), the midday feeding activity by *B. californica* at the outset of the first feeding trial may have been atypical, even for a potentially very hungry slug. However, both feeding trials were conducted in shaded containers held on a black seawater table, and only diffuse, indirect light was used for observation.

Overall, the results reported here strengthen the case that species of *Berthella* are specific to plakinids, especially by documenting the association in a new geographic region. The presence of poecilosclerid sponge spicules in the fecal strands of some individuals of *B. californica* seem likely to have resulted from the incidental ingestion of these sponges, particularly where they may have been overgrown or were otherwise in close contact with a plakinid. However, additional observations and feeding trials are needed to more fully document the diet of both *B. californica* and *B. strongi*. Given MacFarland's (1966, p. 91) observation that *B. strongi* occurs "upon or near compound ascidians," as well as the single record noted above of *B. californica* on *Diplosoma listerianum*, feeding trials might also include compound ascidians. However, it should be noted that *Oscarella carmela*, whose type locality on the Monterey peninsula lies within a few km of where MacFarland collected *B. strongi*, has a slippery, gelatinous texture and has sometimes been mistaken for thinly encrusting compound ascidians (Muricy & Pearse, 2004, p. 609; S. Anderson, personal communication 2 November 2006). Moreover, compound ascidians are often more conspicuous in the under-rock habitat favored by these *Berthella* species than the thin, tan-colored *O. carmela* (personal observations). Finally, as mentioned previously, no *Berthella* species have ever been observed to actually consume ascidians, and for grazing predators of sessile epifauna, substratum often does not equate with prey.

Oscarella carmela was first observed in California in the 1980s in the seawater systems at the Long Marine Laboratory and Monterey Bay Aquarium, leading to questions as to whether the sponge is native or introduced to the NE. Pacific Ocean (Muricy & Pearse, 2004). Predation by *B. californica* and *B. strongi* on *O. carmela*, combined with additional locality records of the sponge from outer coast sites throughout California (personal observations), support the hypothesis that the sponge is native to this region, but had previously been overlooked or misidentified as either a compound ascidian or the dendroceratid slime sponge *Halisarca*.

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